The MODIS Level 3 Near-IR Water Vapor and Cirrus Reflectance Data Products and the Modeling Needs

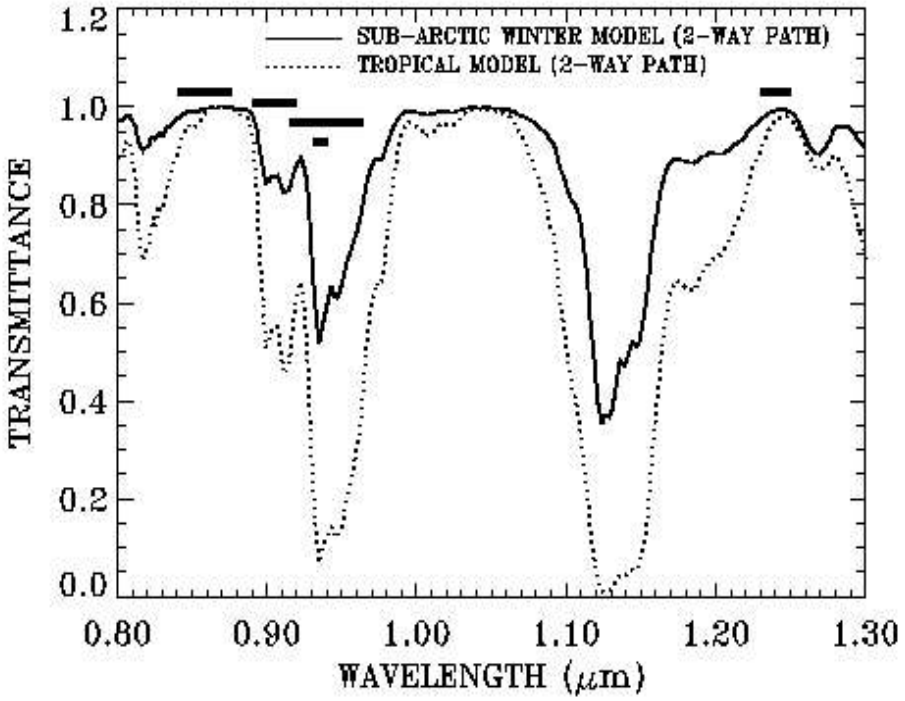
Bo-Cai Gao & Rong-Rong Li

Remote Sensing Division, Code 7232, Naval Research Laboratory, Washington, DC

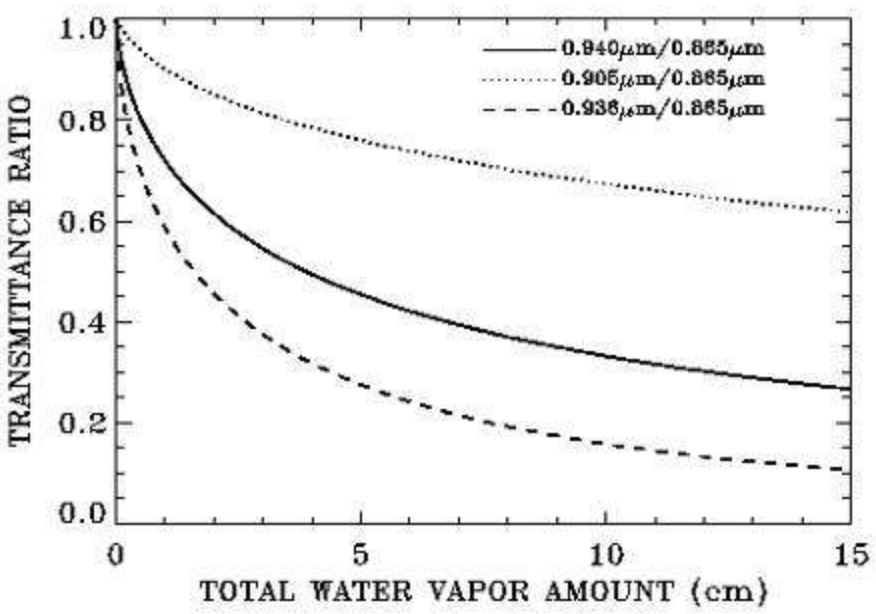
INTRODUCTION

- The operational MODIS near-IR water vapor algorithm.
- Time series (8 years) of the Level 3 MODIS near-IR water vapor products, and modeling needs.
- The operational MODIS cirrus reflectance algorithm.
- Eight-year time series of the Level 3 MODIS cirrus reflectance products, morning and afternoon cirrus differences, and modeling needs.
- Volcano ash detection with the 1.38-micron channel (the idea was first suggested by Bob Fraser in the mid-1990s).
- Summary

The Near-IR Water Vapor Algorithm

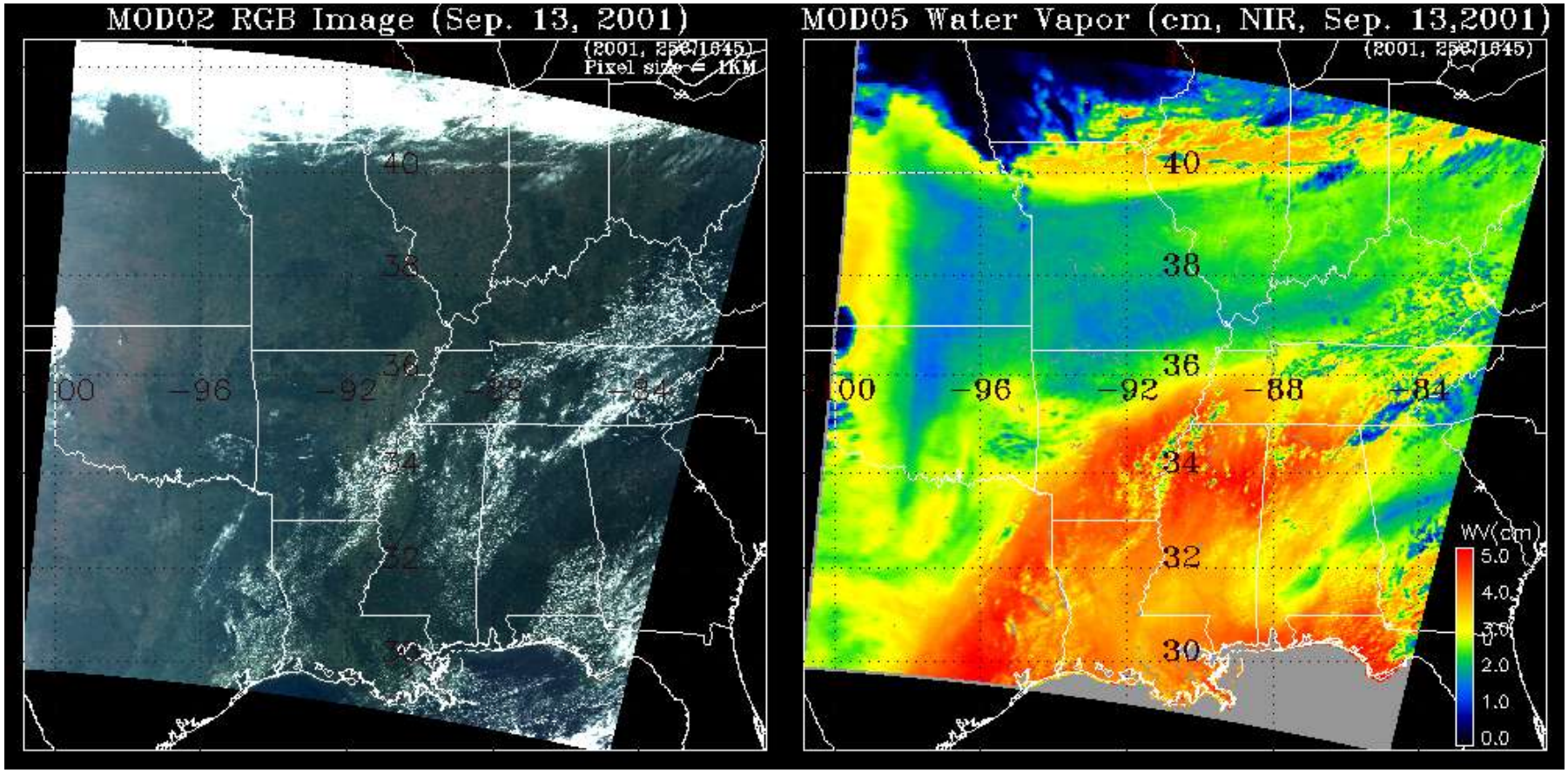


MODIS has 3 water vapor absorption channels near 0.94 micron, and 2 atmospheric window channels near 0.865 and 1.24 micron



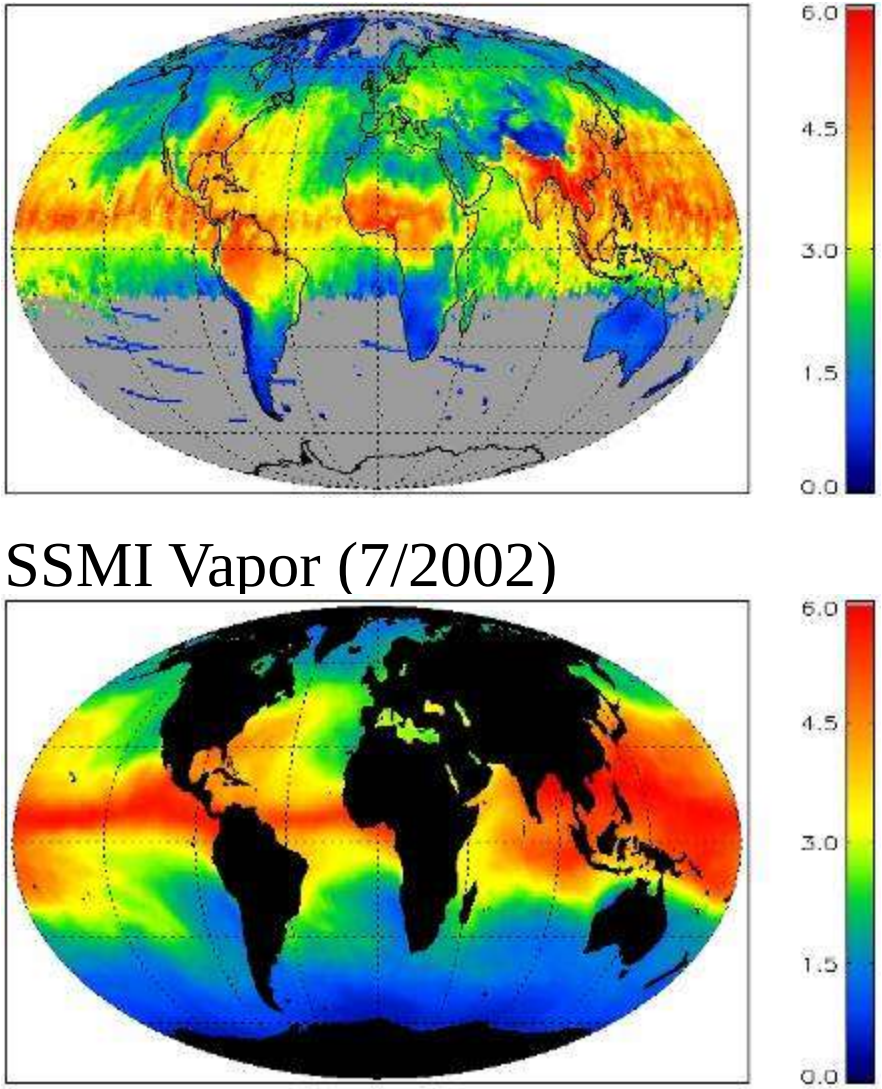
The ratio of absorption channels against window channels allow the derivation of water vapor transmittance, and therefore the amount of water vapor in the atmosphere

A Sample Terra MODIS Water Vapor Image



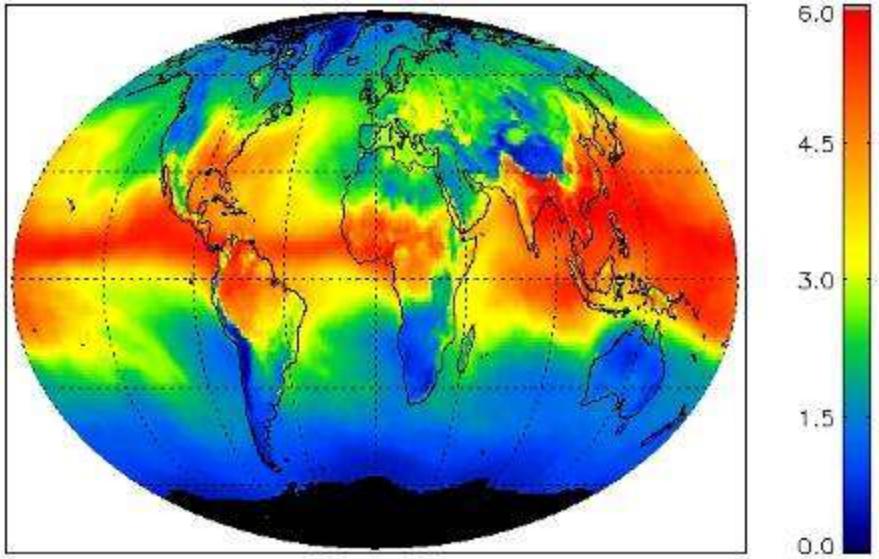
Water Vapor Image (MODIS + SSMI)

MODIS Vapor (7/2002)

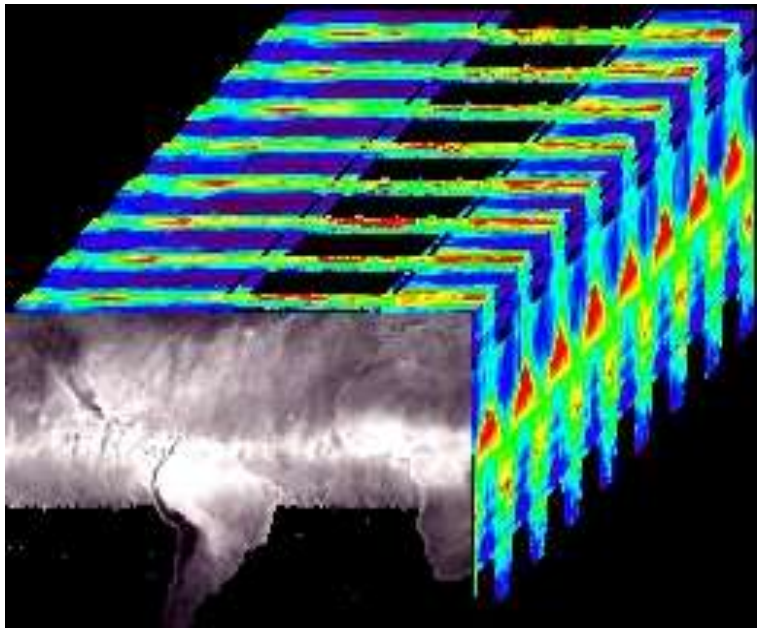


SSMI Vapor (7/2002)

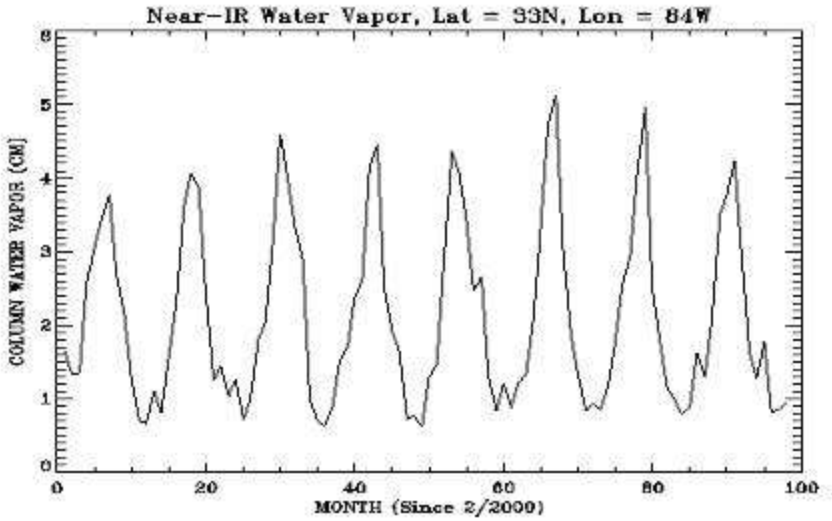
Vapor (MODIS + SSMI)



Near-IR Water Vapor Image Cube



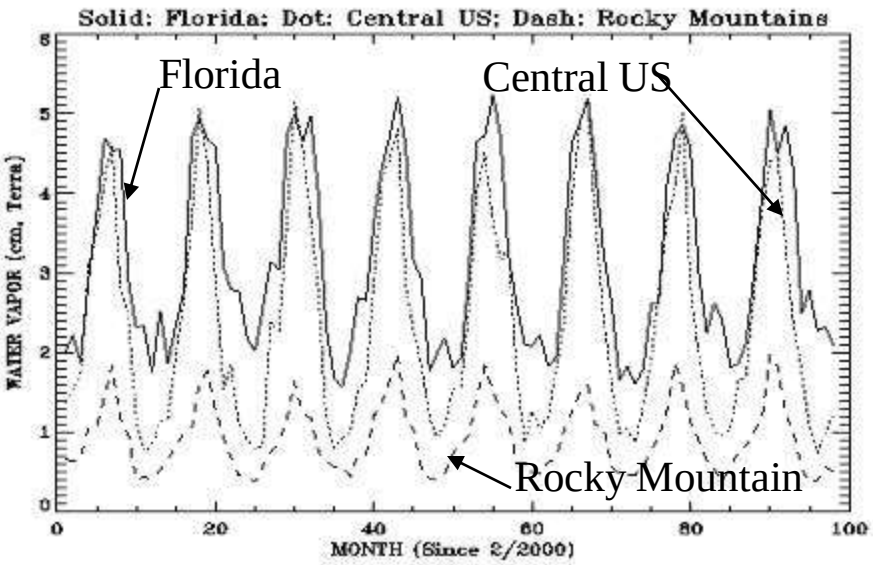
In order to facilitate the analysis of multi-year MODIS data, we stacked a total of 98 monthly-mean MODIS near-IR water vapor images (2/2000 – 3/2008) together to form a 3-D image cube (Lon, Lat, time (month)). This allows us to view spatial and temporal variations easily using commercially available software. A sub-set of the 3-D cube is illustrated in the left.



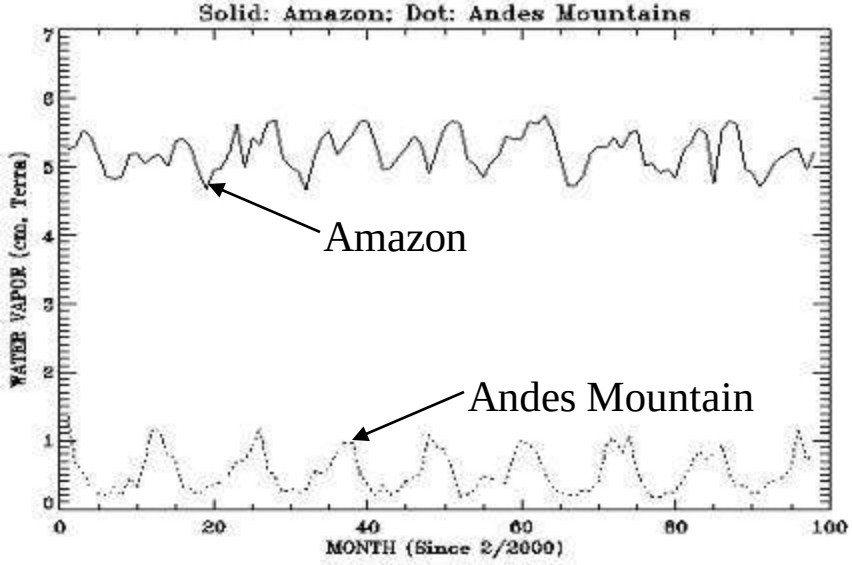
An example of time series of data set at 33N & 84W (~ Georgia) is shown here. The water vapor values last summer were significantly smaller than the previous two summers.

Additional Sample Time Series of Data

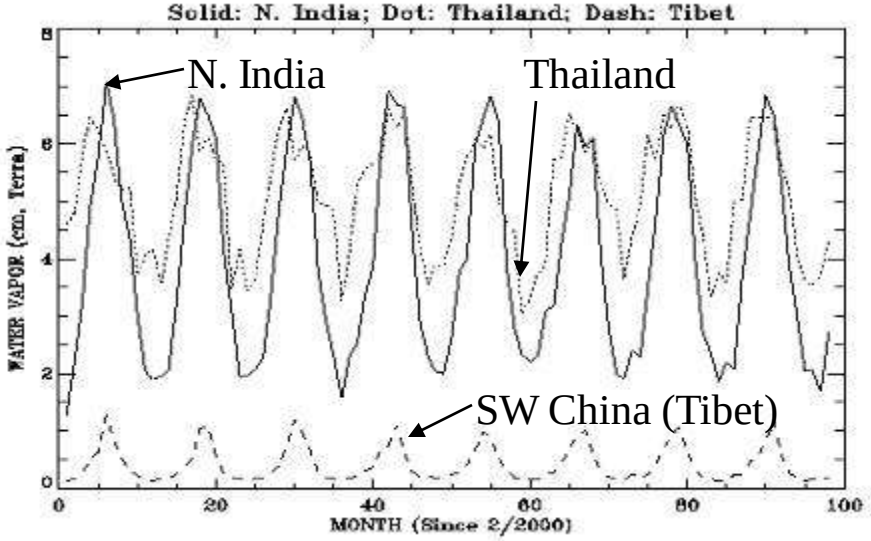
US



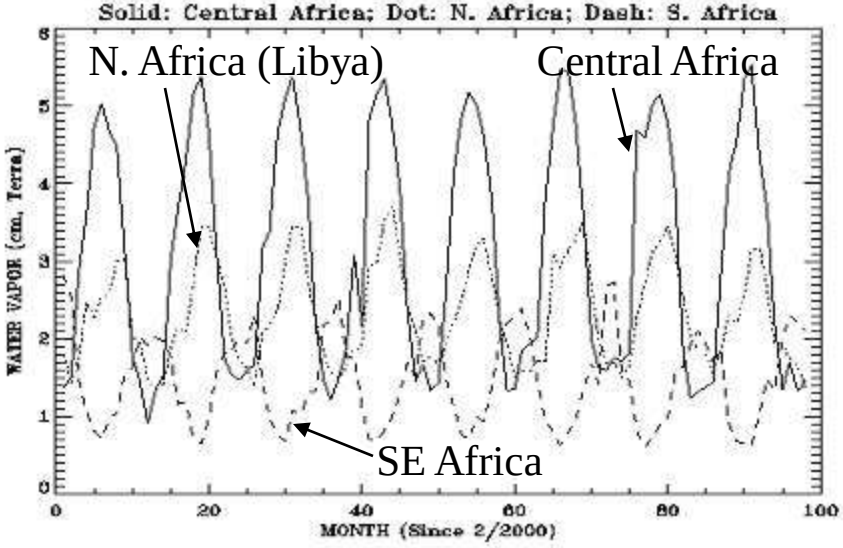
S. America



Asia

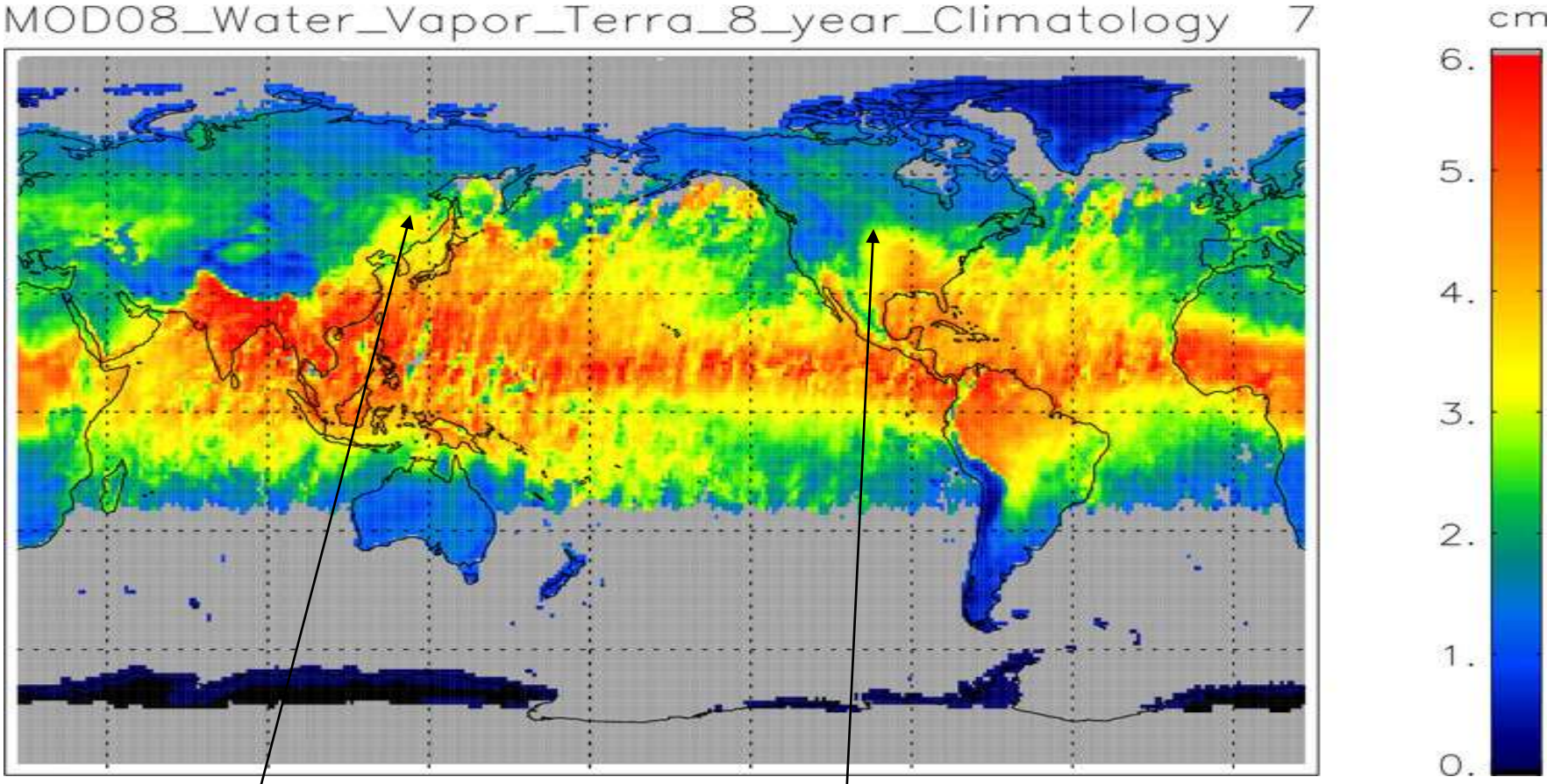


Africa



Averaging of 8-year Monthly-Means & Creation of a Mean Water Vapor Climatology

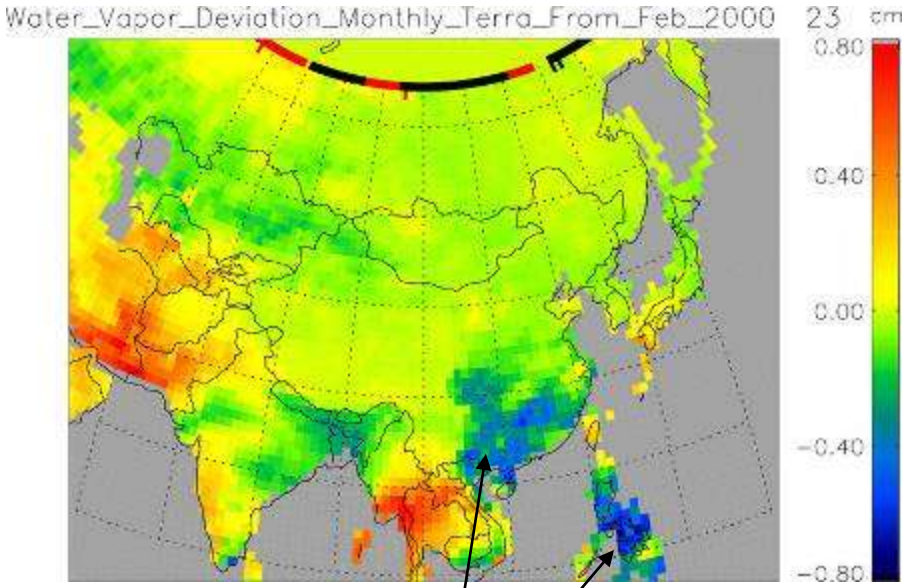
An Example For July



Sample Vapor Deviations From the 8-Year Mean Climatology

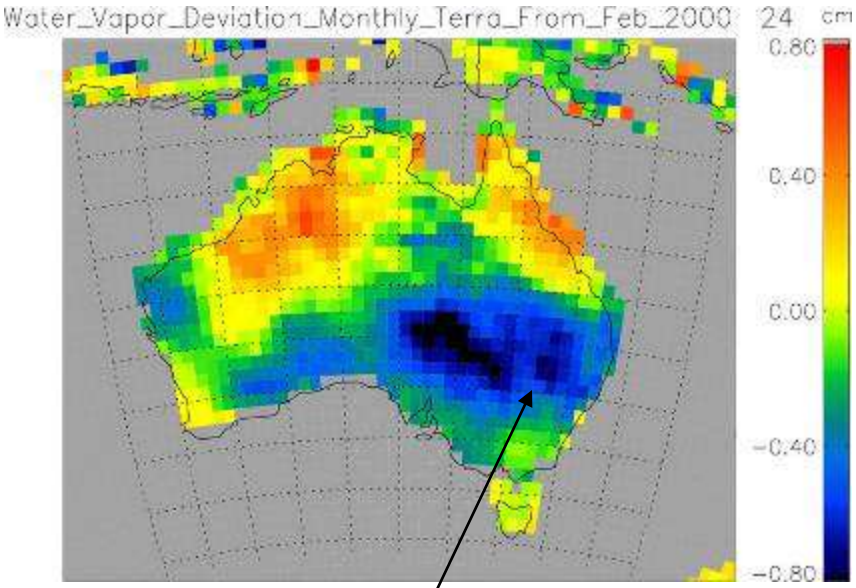
For the 2001 – 2002 El Nino

December 2001



Dry in SE China & Philippines

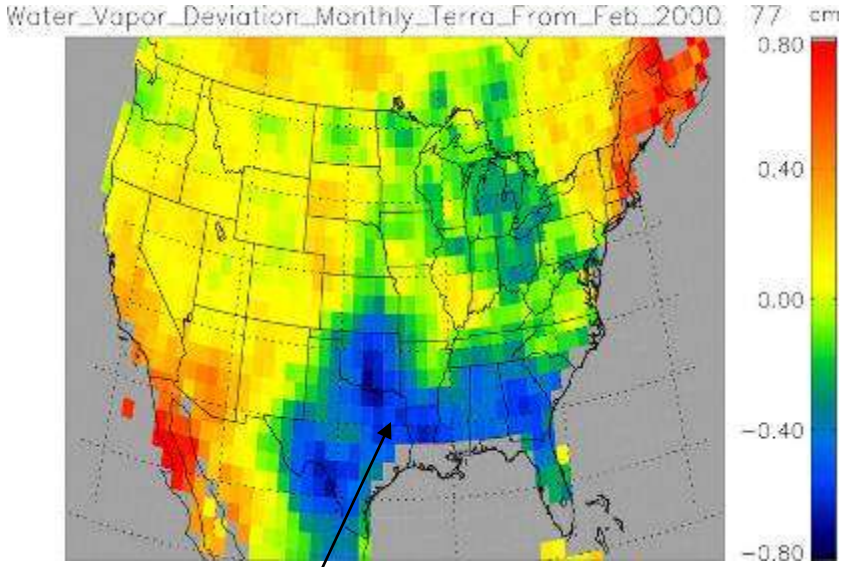
January 2002



Very Dry in SE Australia, intense fire images were shown on TV at the time.

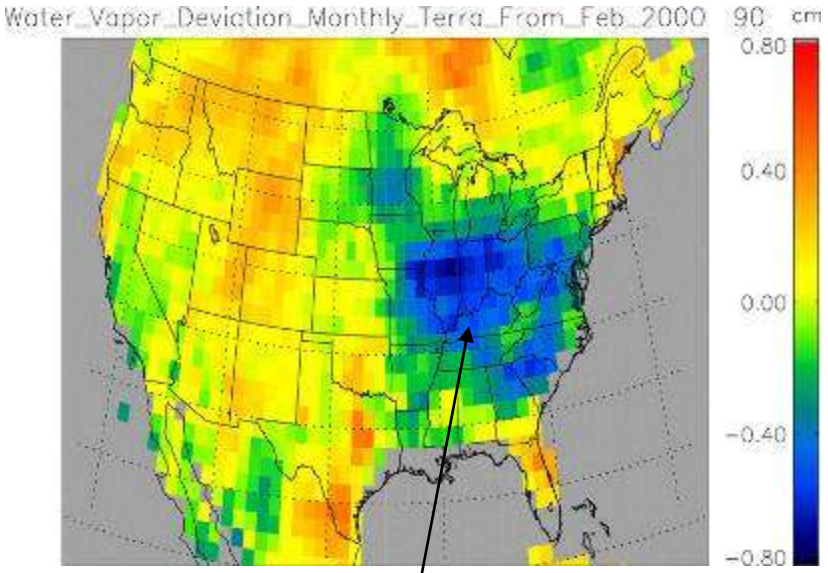
Additional Sample Vapor Deviations From Climatology

June 2006



Dry in southern US

July 2007



Dry in eastern US

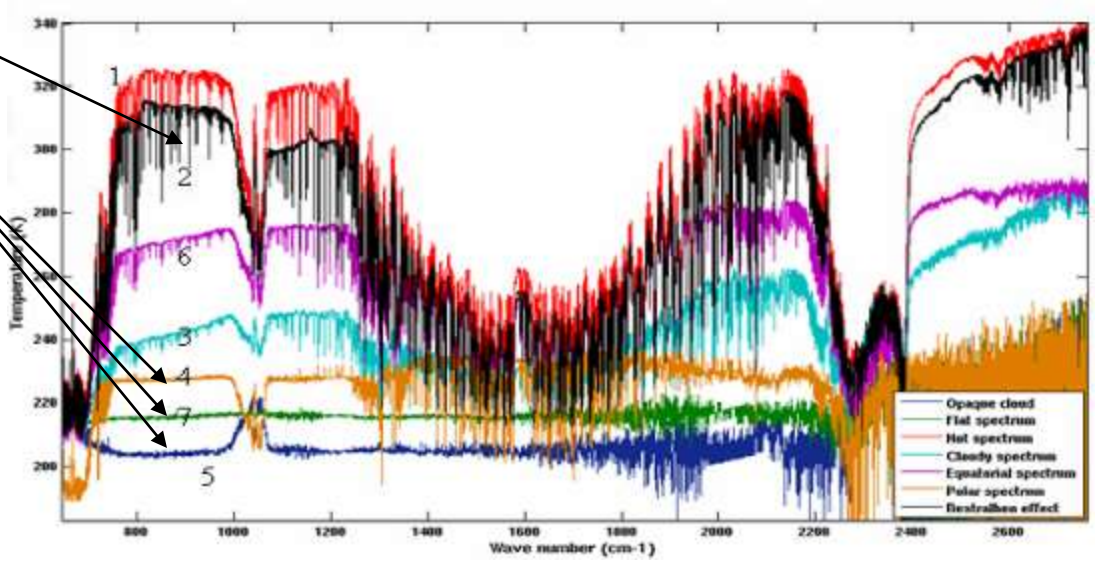
The Prospect on Continuing the Near-IR Water Vapor Climatology

- Good news - Terra & Aqua MODIS instruments may be operational till ~2014 to 2015. The MODIS data may allow us to produce a reasonably long term near-IR water vapor climatology over land.
- Bad news – Future satellite sensors, such as VIIRS and SGLI, will no longer carry near-IR water vapor channels.
- Many researchers think that IR emission channels alone are sufficient for accurate retrievals of atmospheric temperature and water vapor profiles. This is not true in many situations. In reality, IR emission measurements are mostly sensitive to temperature, not as sensitive to atmospheric gas amounts, unlike the near-IR measurements.

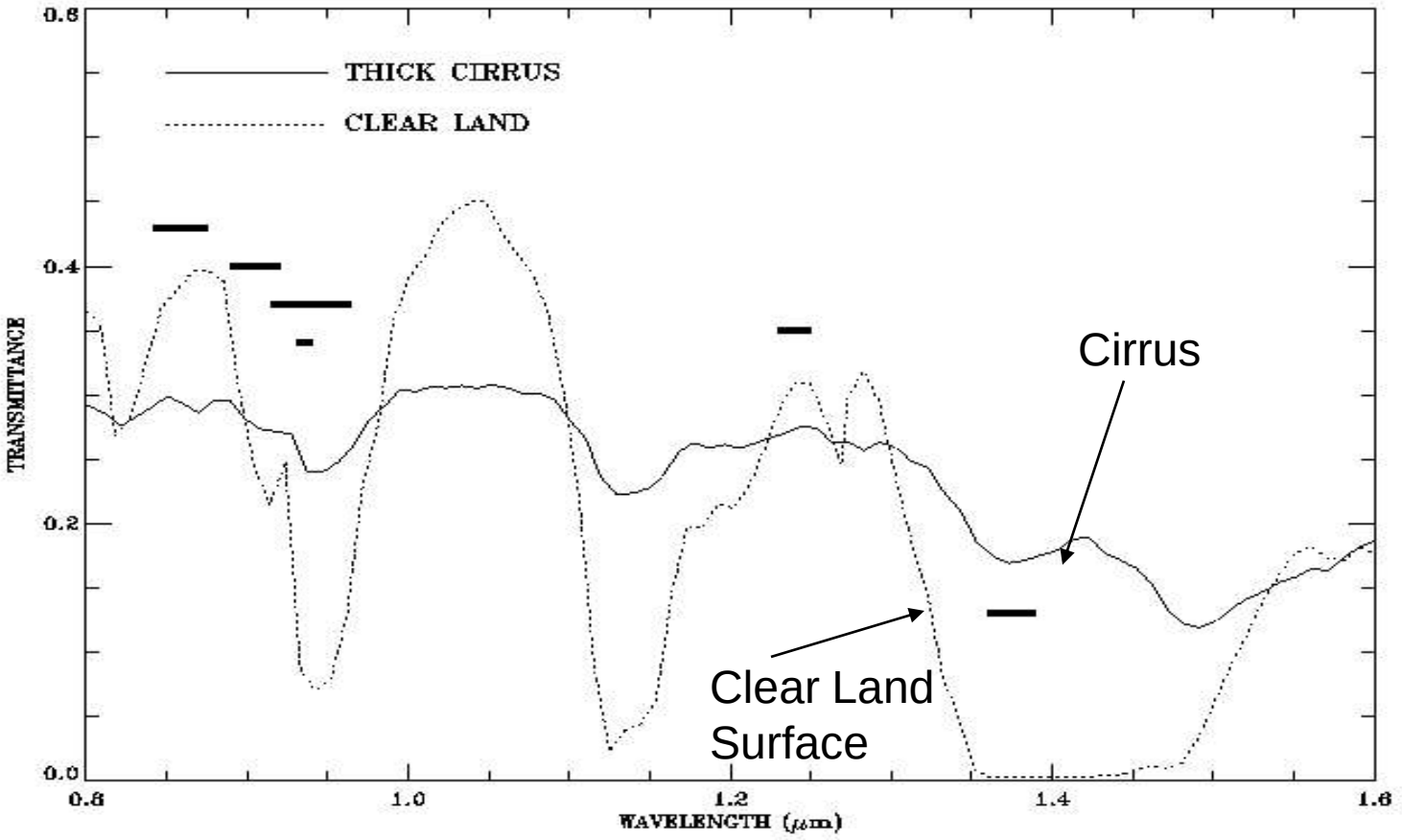
H2O Lines

Sample EU IASI Spectra from T. Phulpin et al. on SPIE

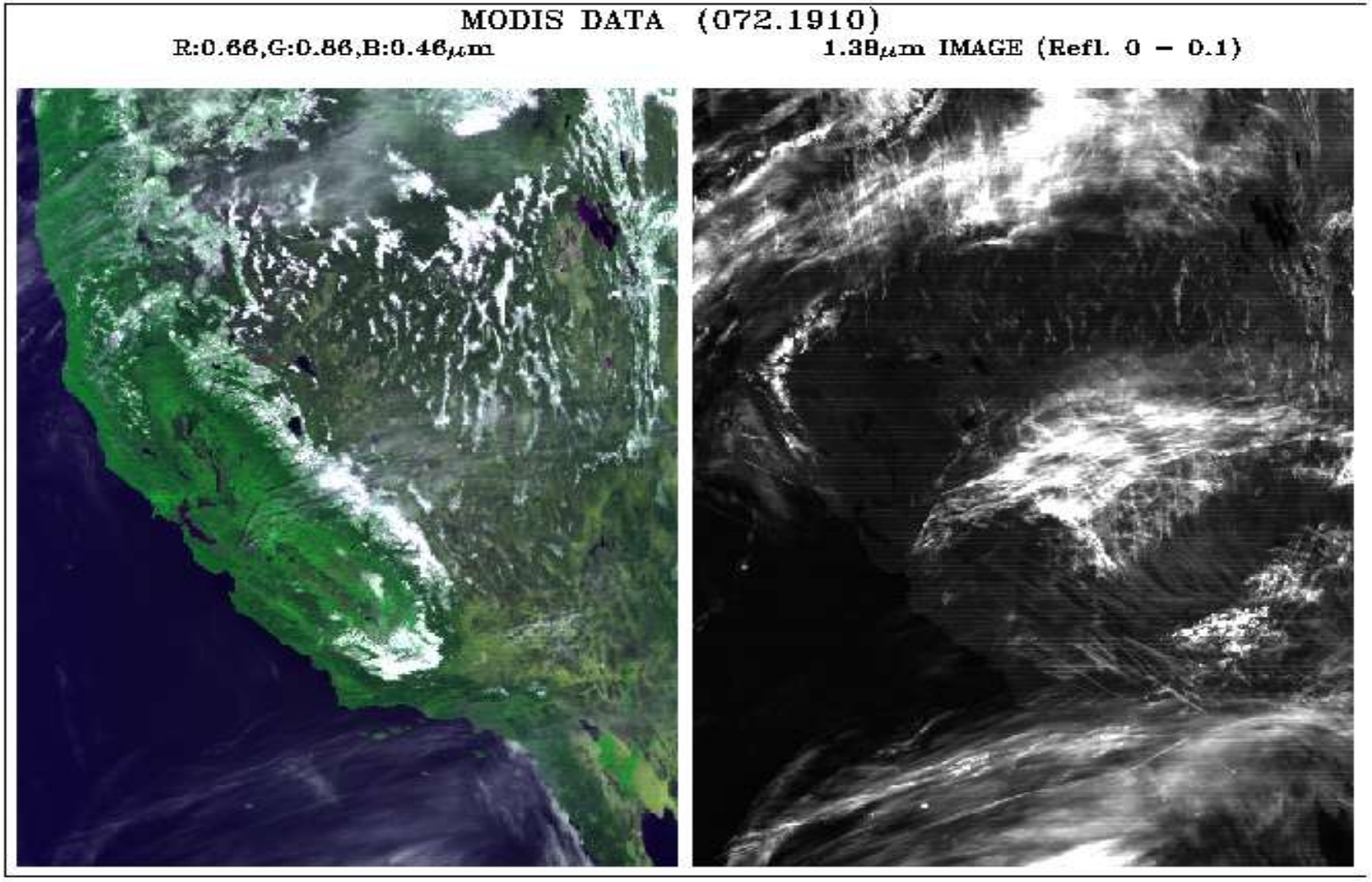
The sample EU IASI Spectra (#4, #5, #7) contain very little info on atmospheric water vapor, although the spectra have several thousand channels → indicating limitations with IR measurements for water vapor retrievals.



Cirrus Detection Approach



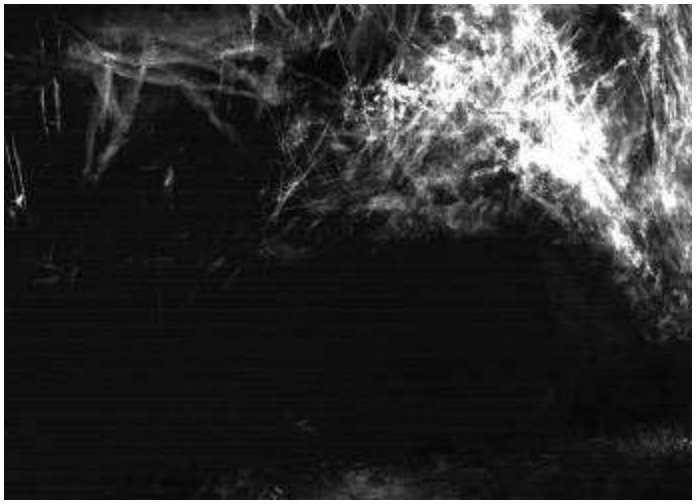
An Example of Cirrus Detection Over Western US



An Example of Cirrus Detection & Correction

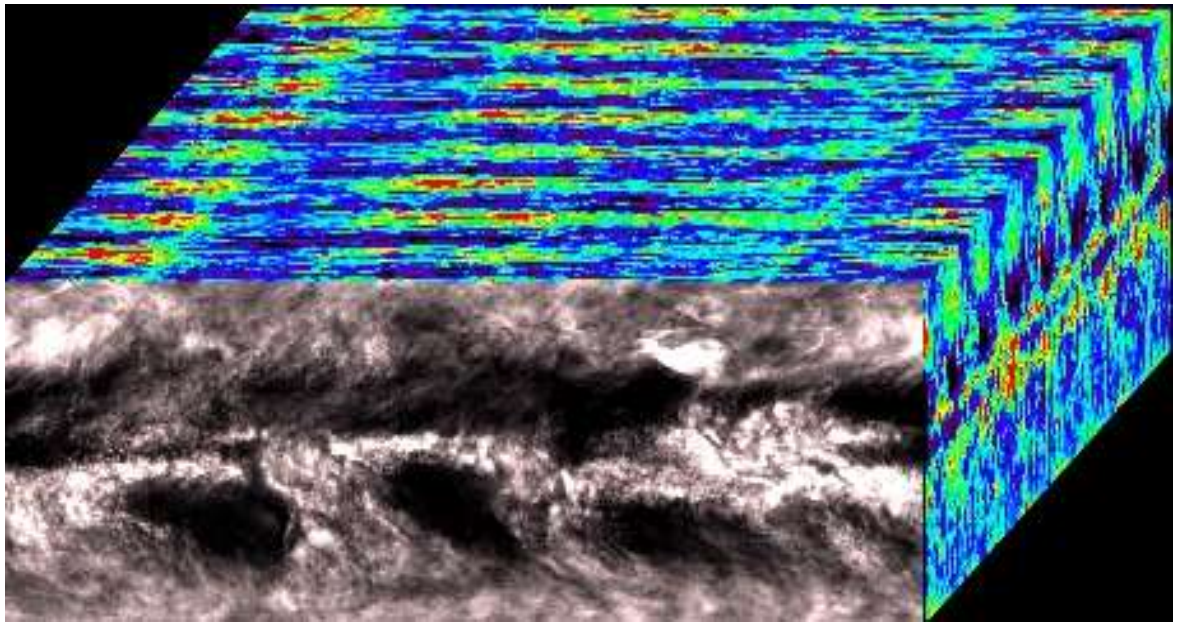
MODIS Original RGB Image

1.38-μm MODIS Image

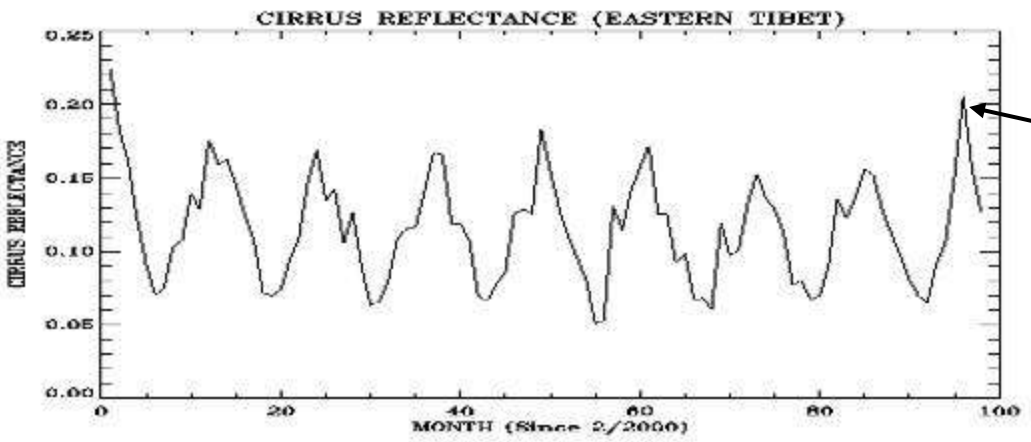


Cirrus-Corrected Image

Cirrus Reflectance Image Cube



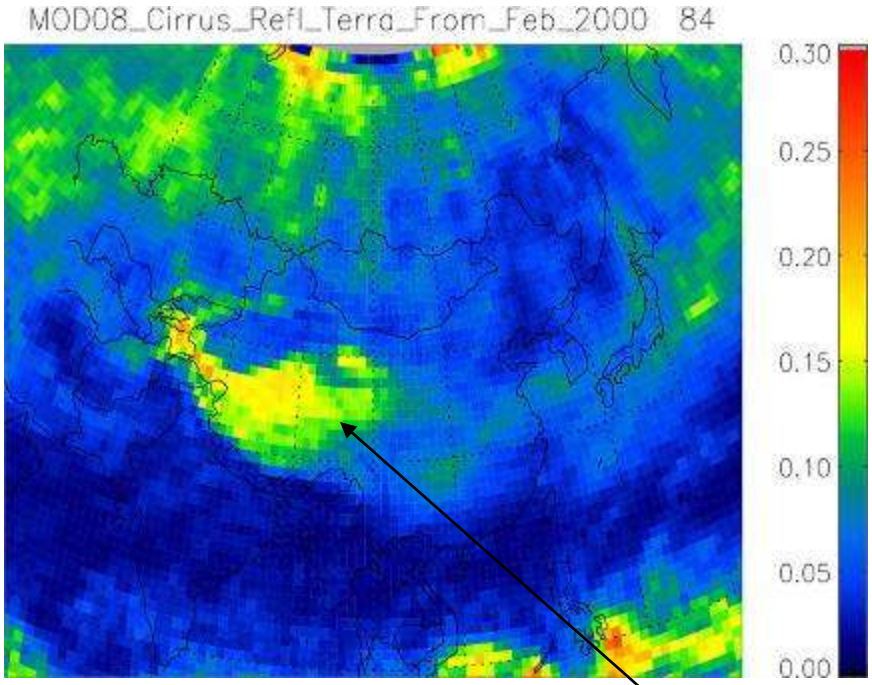
We stacked a total of 98 monthly-mean MODIS cirrus reflectance images (2/2000 – 3/2008) together to form a 3-D image cube (Lon, Lat, time (month)).



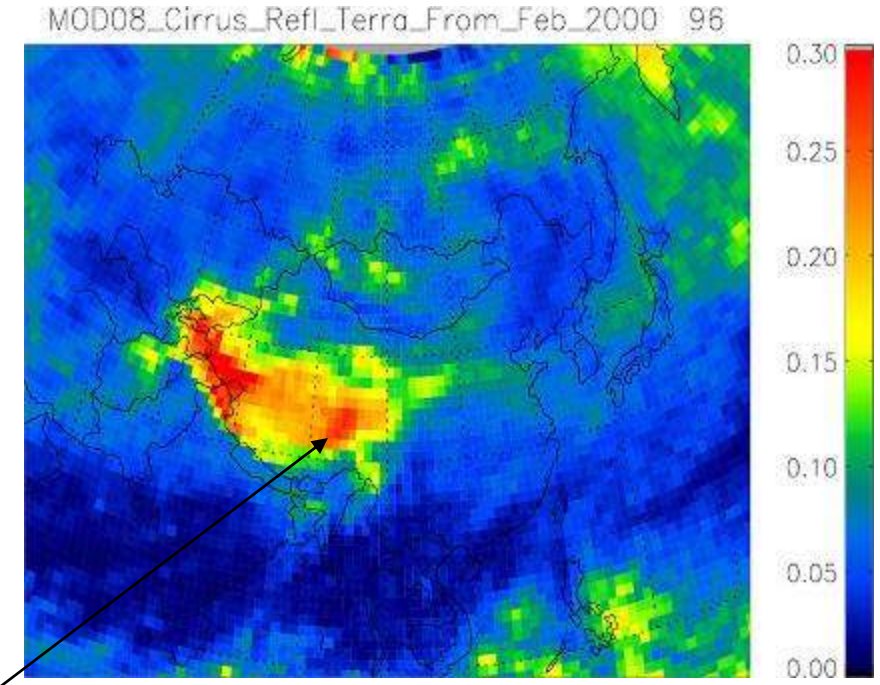
An example of time series of cirrus reflectance data over eastern Tibet of China is shown here. A **spike** is observed for January 2008, which corresponds to the severe weather conditions in the region.

Examples of Monthly-Means Cirrus Reflectance Data

Asia (January 2007)



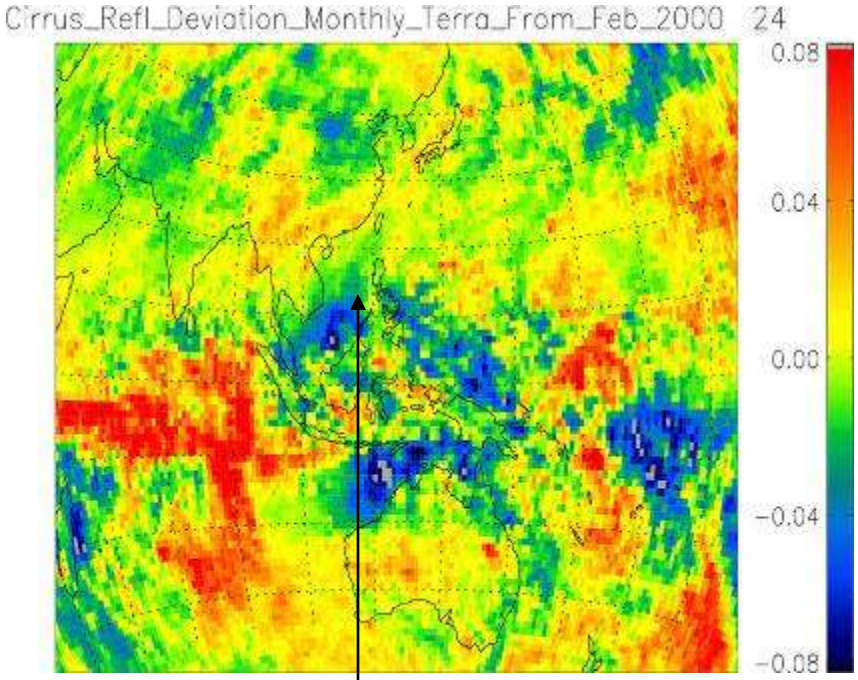
Asia (January 2008, La Nino)



Large differences are observed between
January 2007 & January 2008

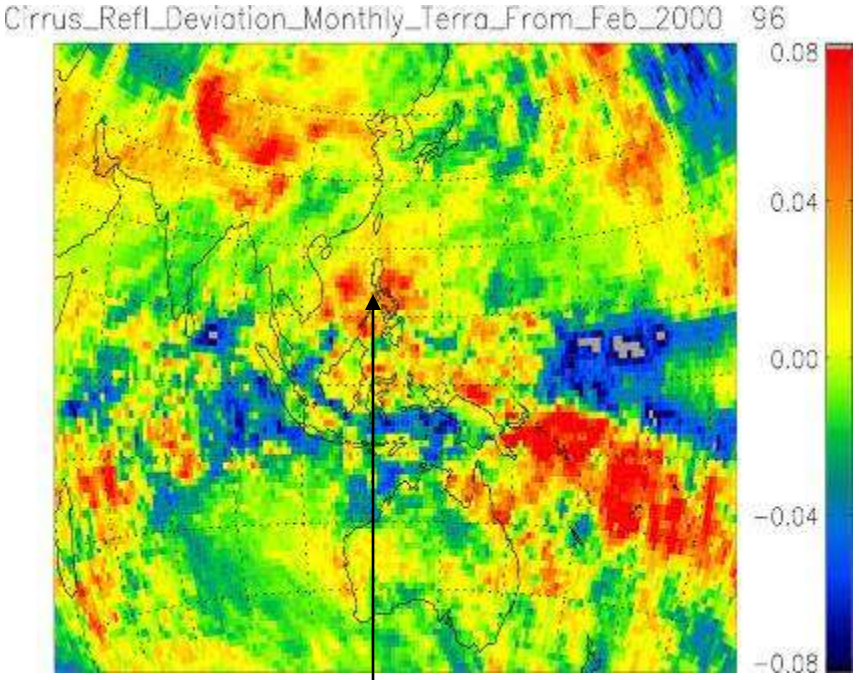
Sample Cirrus Reflectance Deviations From the 8-Year Mean Climatology

January 2002, El Nino



Less cirrus

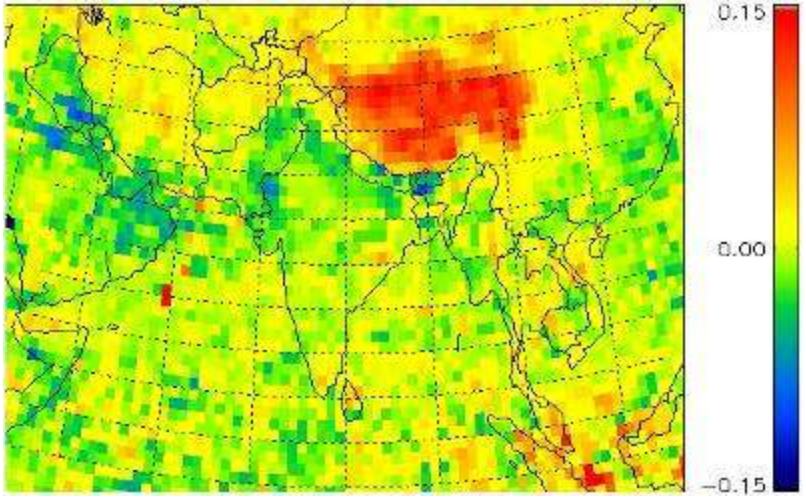
January 2008, La Nino



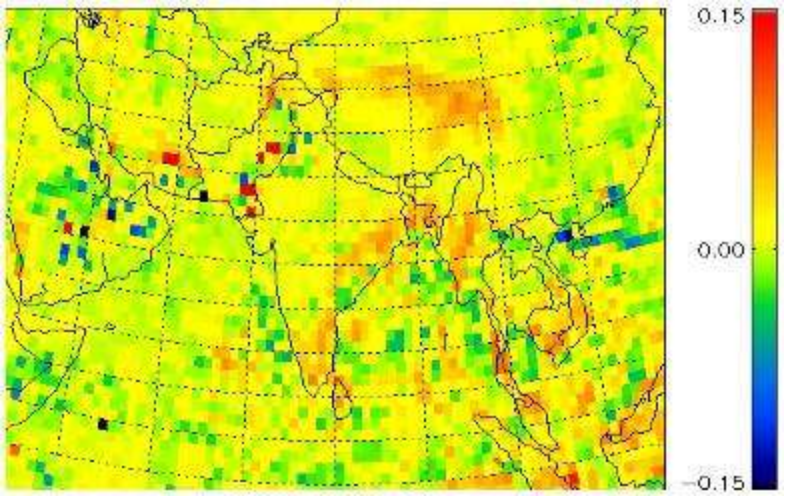
More cirrus

CIRRUS REFL DIFFERENCE (AQUA – TERRA)

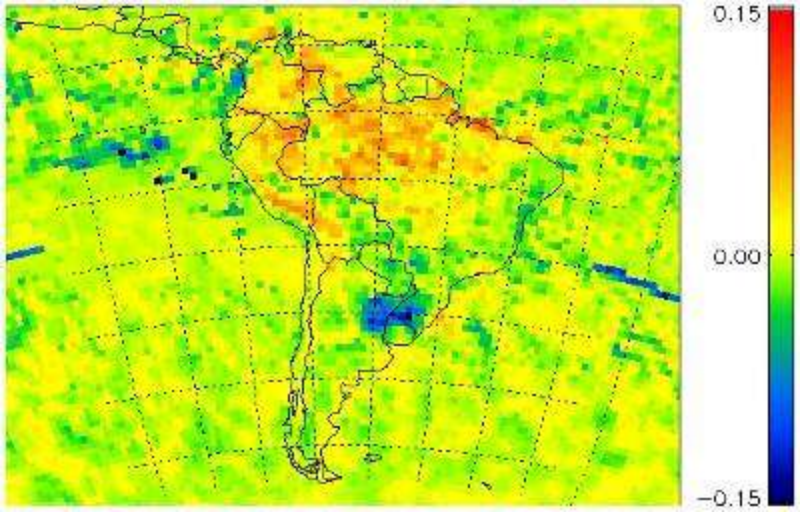
April 2003 (Tibet)



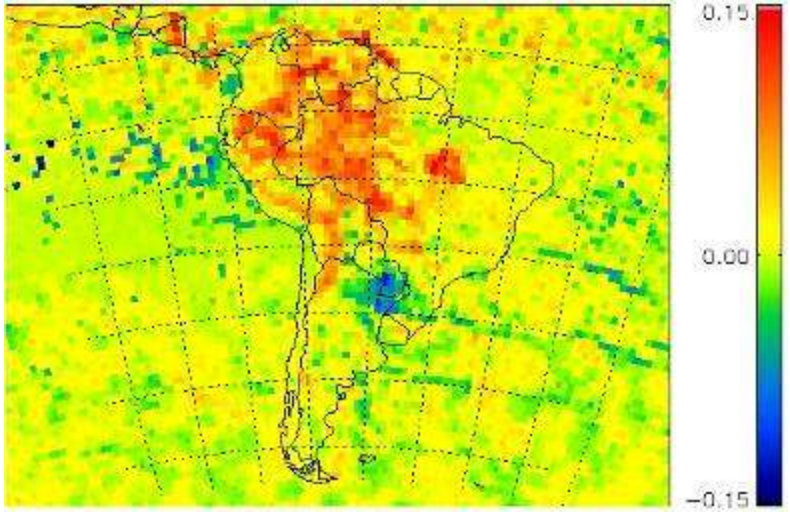
October 2003 (Tibet)



April 2003 (S. America)



October 2003 (S. America)



The Prospect on Continuing the Cirrus Reflectance Climatology

- Terra & Aqua MODIS instruments may be operational till ~2014 to 2015. The MODIS data may allow us to produce a reasonably long term cirrus reflectance climatology globally.

- Future satellite sensors, such as VIIRS, SGLI, GOES-R HES will all carry channels near 1.38-micron for cirrus detections.

- There is a minor concern with the VIIRS 1.378-micron channel, which was specified to have a saturation reflectance of 0.65. This channel will likely saturate over bright tropical clouds.

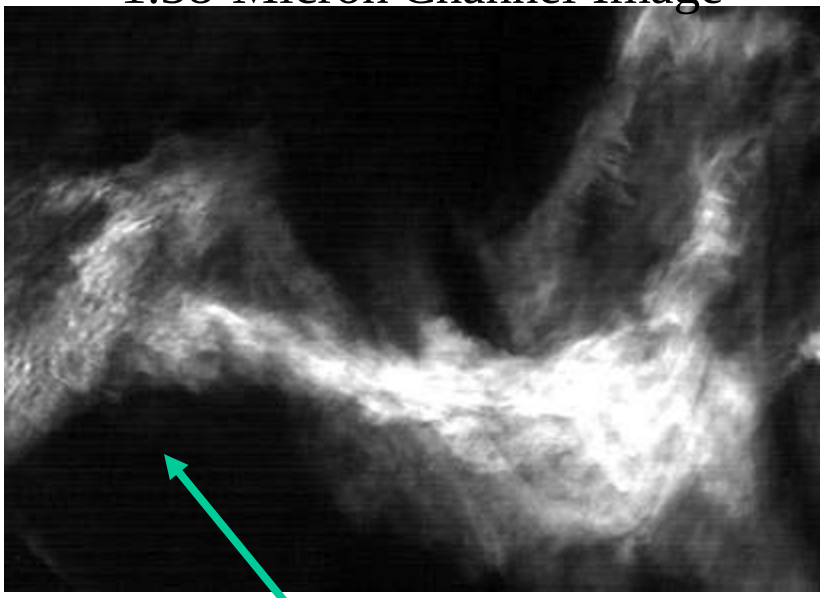
Volcano Ash Detections with the 1.38-micron Channel

(Chile, May 2008, MODIS)

RGB Image (Visible Channels)

(Surface features are seen)

1.38-Micron Channel Image



(Not affected by surface reflection)

Through studies of correlations among the 1.38-micron channel & other channels at 0.41, 0.44, 0.47, 0.55, 0.64, 0.86, 1.24, 1.64, 2.13, 8.6, 11, & 12 micron, we expect to be able get ash reflectance as a function of wavelength, optical depths and particle size distributions, & therefore stratospheric mass loading of ash clouds, which have important climatic effects. The 1991 Pinatubo volcano eruption is a prime example of importance of a major volcano on climate.

Summary

- Global near-IR water vapor and cirrus reflectance products have been derived from MODIS channels in the near-IR spectral region. These data products are quite suited for climate studies. So far, the data sets have hardly been used by the modeling communities to study, for examples, El Nino and La Nino phenomena.

- We have demonstrated, for the first time, that the 1.38-micron channel can be used for the detection of stratospheric volcano ashes. Through more research, we expect to be able to derive the total mass of volcanic ashes injected into the stratosphere, and therefore make a contribution to the study of volcano' climate effects.